Interval Field Model and Interval Finite Element Analysis

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Abstract: Uncertain parameters with inherent spatial variability are commonly encountered in engineering. These include material properties of the heterogeneous media such as concrete or porous rock, external loads such as wind or snow loads applied on structures, etc. This type of uncertain parameters is traditionally quantified by the random field model, while the large amount of information required in construction of the precise probability distribution functions is often difficult to obtain for many practical engineering problems. The authors propose an interval field model to represent the spatial uncertainties with insufficient information, in which the variation of the parameter at any location is quantified only by an interval with the upper and lower bounds. In the interval field model, the spatial dependency can be measured by a covariance function or a correlation coefficient function that defined for the interval variables at different locations. Based on the correlation information, an interval K-L expansion is formulated for the proposed interval field model, by which the continuous spatial uncertainty can be expressed through a series of deterministic functions with uncorrelated interval coefficients. By retaining only the principle terms in the expansion, the truncated interval K-L expansion is given, and the truncation error is also discussed. Furthermore, by introducing the interval field model into the finite element method (FEM), an interval finite element analysis of structures with spatially uncertain parameters is carried out. The perturbation-based interval finite element methods (P-IFEMs) are developed to evaluate the upper and lower bounds of structural responses such as displacement and stress, etc. An interval simulation (IntS) method is also proposed to give a reference solution for structural analysis with interval field. Finally, three numerical examples are investigated to demonstrate the effectiveness of the present interval field model and the developed P-IFEMs.

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